Iron Oxides as Tools to Assess Water Erosion Processes

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The study of erosive processes is essential to maintain agricultural sustainability, but it is often affected by the limitations and costs of conventional methodologies used. This situation is common worldwide, which has resulted in an increasing interest in developing sediment tracers. Here we provide a general review of diverse sediment tracing approaches and some of the advantages and limitations of using iron oxides for tagging soil particles.

The scientific literature provided information on the use of sediment tracers of diverse types in water erosion studies (Figure 1). The great diversity suggests that none of them fulfill all of the requirements as an ideal tracer (Zhang et al., 2001).

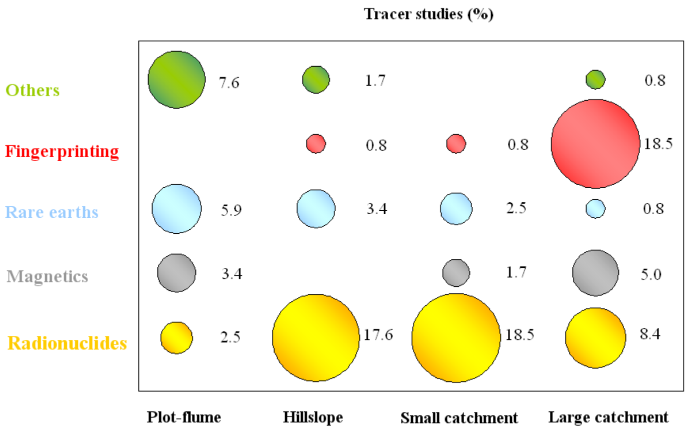

Figure 1. Bubble plot indicating the distribution of erosion studies with tracers by scale and kind of tracer (Guzmán et al., 2013).

Iron oxides (magnetite, hematite and goethite) are solid pigments used for construction, and can be easily purchased at low cost. Guzmán et al. (2010) evaluated the suitability of tagging soil with magnetite in soils of different textural classes. They observed a slight increase in susceptibility in the smaller aggregates (< 63 µm), that was also correlated with higher clay contents. Guzmán et al. (2015) observed a decreasing tracer distribution with depth of the tagged soil profile. Both features have to be calibrated and considered when this technique is used in a specific experiment (e.g. Guzman et al., 2013, 2015). The potential of using magnetite as a tracer was also evaluated through simulated rainfall trials, obtaining a precision of approximately 0.5 kg m^{-2} for sediment loss. This suggests its suitability for evaluating relatively large cumulative soil losses or in combination with other techniques.

In a field experiment, Guzmán et al. (2013) applied magnetite at the plot scale to estimate soil losses and sediment sources in a rain-fed intensively-managed olive orchard, distinguishing erosion rates among tree rows (tr), inter tree rows (itr), and rills (r), (Figure 2). In a ridged system, origins of sediment and soil

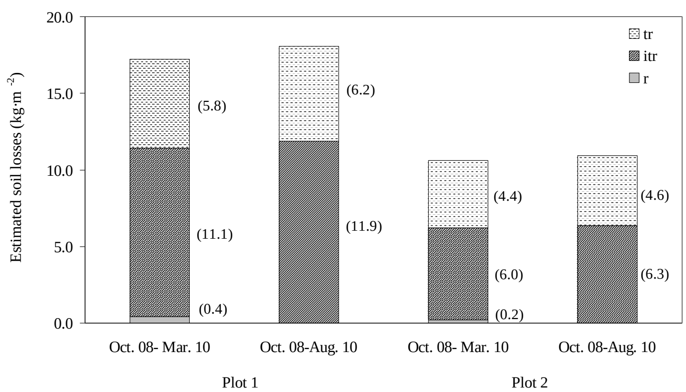

Figure 2. Estimated soil losses from each zone (tr-tree rows; itr-inter tree rows; r-rills) within the plots for the monitored periods using magnetite tracer (Guzmán et al., 2013).

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movement along furrows were evaluated with rainfall simulations and sprinkler irrigation at different growth stages of the crop and under two soil managements (with and without wheel tracks) by applying magnetite, hematite and goethite (Guzmán et al., 2015). They determined that with bare soil, the contribution of these zones was almost 90% of the total sediment while that trend was reversed with standing crop residues. Iron oxides not only provided helpful information to act on local problems but also facilitated the calibration and setup of soil erosion models (e.g. KINEROS2), which can help to extrapolate results to other conditions beyond those considered in the experiment (Figure 3).

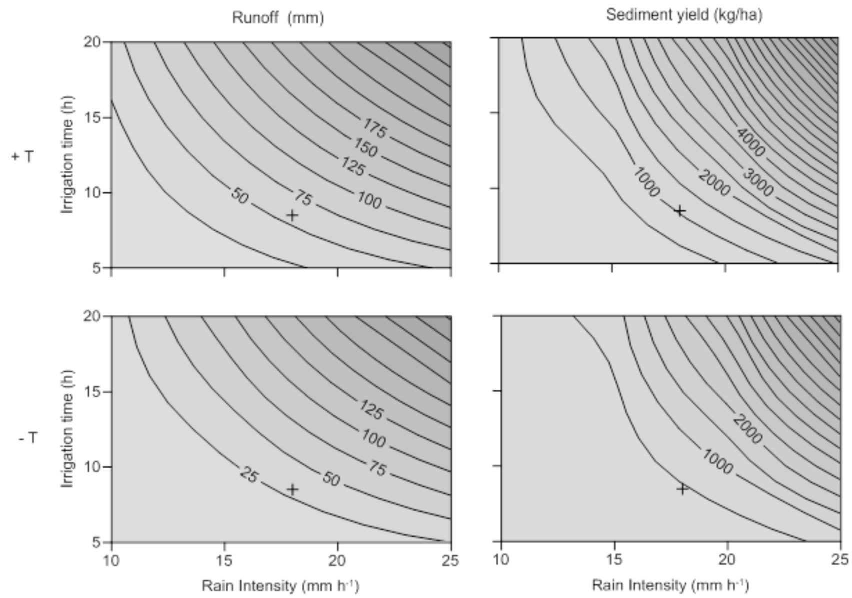

Figure 3. Generated runoff and sediment yield for different irrigation combinations of intensity and duration on furrows with (+T) and without (-T) wheel tracks (Guzmán et al., 2015).

After characterizing iron oxides, and their subsequent application in trials at different levels, promising results have been obtained. Soil loss and erosion rates of different areas within an agricultural system can be estimated with enough accuracy for many experimental requirements. Their moderate cost, relative simplicity of the analysis, and non-destructive nature of the measurements, confers to these substances ideal characteristics to be a powerful complement and/or alternative tool in assessing the sustainability of agricultural systems. Use of iron oxides as tracers is an innovative approach that requires further evaluation under other conditions, and solving issues not fully addressed in experiments conducted to this point.

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